CHAPTER 5 Review

REFLECTING ON CHAPTER 5

- Work is defined as the product of force times displacement. In general, if the force acts at an angle (θ) to the displacement, the work done by the force is given by $W = F\Delta d \cos\theta$.
- The work done by an applied force equals the change in energy produced by that applied force.
- Kinetic energy is expressed as $E_k = \frac{1}{2}mv^2$.
- Gravitational potential energy for positions near Earth's surface is expressed as $E_g = mg\Delta h$.
- An isolated system is one that neither gains energy from its environment nor loses energy to its environment.
- The law of conservation of energy states that, in an isolated system, the total energy is conserved, but can be transformed from one form to another.
- For an ideal spring, the restoring force is proportional to the amount of extension or compression of the spring. This is expressed as $F = -kx$, where k is the spring constant. The applied force that causes the spring to stretch (or compress) is equal in magnitude and opposite in direction to the restoring force: $F_a = kx$
- The amount of elastic potential energy stored in a spring is equal to the area under the force-extension (or compression) graph for the spring. It can be calculated from $E_e = \frac{1}{2}kx^2$.
- Applied forces are conservative if the amount of work that they do on an object as it moves between two points is independent of the path of the object between those points.
- Applied forces are non-conservative if the amount of work that they do on an object as it moves between two points is dependent on the path of the object between those points.
- Work done by an object on its environment is negative work and decreases the total energy of that object. Work done on an object by its environment is positive work and increases the total energy of the object.

Knowledge/Understanding

1. Explain what happens to the total mechanical energy over a period of time for open systems, closed systems, and isolated systems.

2. Write a general equation that relates the change in mechanical energy in systems to the amount of work done on it and the amount of heat lost by it.

3. You wind up the spring of a toy car and then release it so that it travels up a ramp. Describe all of the energy transformations that take place.

4. Compare how the everyday notion of work as "exerting energy to complete a task" differs from the physical definition of work.

5. Explain the sign convention for designating whether work is being done by an object on its environment or whether the environment is doing work on an object.

6. **(a)** Explain whether work done by a frictional force on an object can be positive.
(b) Explain when the work done by the restoring force of a spring on a mass is considered to be positive and when it is considered to be negative with respect to the mechanical energy of the mass.
(c) Discuss your answers to the above questions in terms of conservative and non-conservative forces.

7. Define and give an example of periodic motion.

Inquiry

8. Imagine taking a spring of 10 coils and cutting it in half. Will each smaller spring have a smaller, larger, or the same spring constant as the larger spring? (Hint: Consider the force required to compress the large and small springs by the same amount.)

9. A basic clock consists of an oscillator and a mechanism that is "turned" by the oscillator (to count the oscillations). Design a clock based on a simple pendulum or other oscillating device, using readily available materials. If possible, construct the clock and determine its accuracy. Even if you are not successful in constructing a functional clock, outline the technological challenges that you encountered.

10. The transformation of energy between kinetic and potential forms in an ideal simple harmonic oscillator can be modelled mathematically by writing a total mechanical energy equation for specified points during its motion. Consider a spring attached to a wall at floor level. A block of wood is attached to the other end of the spring so that the block can oscillate across the floor in a horizontal plane. Assume that the floor is frictionless. Set a frame of reference for the spring so that the equilibrium position of the system is $x = 0$ and the maximum displacements of the block is $x = -A$ and $x = +A$. Set the block of wood in motion by pulling it back to position +A.
    - **(a)** Write expressions for the total energy of the system at points –A, +A, and zero.
    - **(b)** At which of the three above points is the kinetic energy at its maximum and at its minimum?
    - **(c)** At which of the three points is the velocity at its maximum and at its minimum?
    - **(d)** Sketch a graph of energy versus position with individual curves for the elastic potential energy and the kinetic energy of the block as it oscillates. What is the geometrical shape of each curve?
    - **(e)** Sketch a velocity-versus-position graph.

11. Bowling balls need to be returned promptly from the end of the alley so that they can be used again. Sketch a ball-return system that requires no external energy source. Explain the energy transformations involved in the operation of your system. Identify the conservative and non-conservative forces that need to be taken into consideration. What features does the design include to minimize wear and tear on the bowling balls, despite their large mass?

Communication

12. Imagine that you are moving a negatively charged sphere toward a Van de Graaff generator. As you bring the sphere closer, does the energy of the system increase or decrease? Explain your reasoning.

13. Each of three stones is displaced to a vertical height of *h*. Stone R is placed on the top of a ramp, stone P is at the end of a taut pendulum string, and stone G is simply held above the ground. Do each of these stones have the same gravitational potential energy?
    - **(a)** If frictional forces are neglected, will each stone have the same kinetic energy at the instant before it reaches the bottom of its path? Explain your reasoning.
    - **(b)** If you consider likely frictional forces, will each stone have the same kinetic energy at the instant before it reaches the bottom of its path?
    - **(c)** Use the above two examples to differentiate between conservative and non-conservative forces.

14. A child descends a slide in the playground. Write expressions to show the total mechanical energy of the child at the top, halfway down, and at the bottom of the slide. Write a mathematical expression that relates the energy total at the three positions.

Making Connections

15. When stretched or compressed, a spring stores potential energy. Make a list of other common devices that store potential energy when temporarily deformed.

16. Research and write a brief report about how chemists use the concept of ideal springs to model the action of the bonds holding atoms together in molecules.

17. Car bumper systems are designed to absorb the impact of slow-speed collisions in such a way that the vehicles involved sustain no permanent damage. Prepare a presentation on how a bumper system works, including an explanation of the energy transformations involved.

Problems for Understanding

18. A 0.80 kg block of wood has an initial velocity of 0.25 m/s as it begins to slide across a table. The block comes to rest over a distance of 0.72 m.
    (a) What is the average frictional force on the block?
    (b) How much work is done on the block by friction?
    (c) How much work is done on the table by the block?
19. A 1.5 kg book falls 1.12 m from a table to the floor.
    (a) How much work did the gravitational force do on it?
    (b) How much gravitational potential energy did it lose?
20. A 175 kg cart is pushed along level ground for 18 m, with a force of 425 N, and then released.
    (a) How much work did the applied force do on the cart?
    (b) If a frictional force of 53 N was acting on the cart while it was being pushed, how much work did the frictional force do on the cart?
    (c) Determine how fast the cart was travelling when it was released.
    (d) Determine how far the cart will travel after it is released.
21. A man is pushing a 75 kg crate at constant velocity a distance of 12 m across a warehouse. He is pushing with a force of 225 N at an angle of 15˚ down from the horizontal. The coefficient of friction between the crate and the floor is 0.24. How much work did the man do on the crate?
22. A boy, starting from rest, does 2750 J of work to propel himself on a scooter across level ground. The combined mass of the boy and scooter is 68 kg. Assume friction can be neglected.
    (a) How fast is he travelling?
    (b) What is his kinetic energy?
    (c) If he then coasts up a hill, to what vertical height does he rise before stopping?
23. While coasting on level ground on a bicycle, you notice that your speed decreased from 12 m/s to 7.5 m/s over a distance of 50.0 m. If your mass combined with the bicycle's mass is 65 kg, calculate the average force that opposes your motion.
24. A 0.50 kg air puck is accelerated from rest with a force of 12.0 N. If the force acts over 45 cm and the surface is frictionless, how fast is the puck going when it is released?
25. If 25 N are required to compress a spring 5.5 cm, what is the spring constant of the spring?
26. (a) What is the change in elastic potential energy of a spring that has a spring constant of 120 N/m if it is compressed by 8.0 cm?
    (b) What force is required to compress the spring by 8.0 cm?
27. A 0.500 kg mass resting on a frictionless surface is attached to a horizontal spring with a spring constant of 45 N/m. When you are not looking, your lab partner pulls the mass to one side and then releases it. When it passes the equilibrium position, its speed is 3.375 m/s. How far from the equilibrium position did your lab partner pull the mass before releasing it?
28. A mass m_1 is hung on a spring and stretches the spring by $x = 10.0$ cm. What is the spring constant in terms of the variables?
29. A dart gun has a spring with a constant of 74 N/m. An 18 g dart is loaded into the gun, compressing the spring from a resting length of 10.0 cm to a compressed length of 3.5 cm. If the spring transfers 75% of its energy to the dart after the gun is fired, how fast is the dart travelling when it leaves the gun?

30. A 12 g metal bullet (specific heat capacity: $c = 669$ J/kg°C) is moving at 92 m/s when it penetrates a block of wood. If 65% of the work done by the stopping forces goes into heating the metal, how much will the bullet's temperature rise in the process?

31. Consider a waterfall that is 120 m high. How much warmer is the water at the bottom of the waterfall than at the top? (The specific heat of water is 4186 J/kg °C.)

32. A spring with a constant of 555 N/m is attached horizontally to a wall at floor level. A 1.50 kg wooden block is pushed against it, compressing the spring by 12 cm, and then released.
   (a) How fast will the block be travelling at the instant it leaves the spring? (Assume that friction can be ignored and that the mass of the spring is so small that its kinetic energy can be ignored.)
   (b) If the block of wood travels 75 cm after being released and then comes to rest, what friction force opposes its motion?

33. A simple pendulum swings freely and rises at the end of its swing to a position 8.5 cm above its lowest point. What is its speed at its lowest point?

34. A 50.0 g pen has a retractable tip controlled by a button on the other end and an internal spring that has a constant of 1200 N/m. Suppose you hold the pen vertically on a table with the tip pointing up. Clicking the button into the table compresses the spring 0.50 cm. When the pen is released, how fast will it rise from the table? To what vertical height will it rise? (Assume for simplicity that the mass of the pen in concentrated in the button.)

35. A spring with a spring constant of 950 N/m is compressed 0.20 m. What speed can it give to a 1.5 kg ball when it is released?

36. A basketball player dunks the ball and momentarily hangs from the rim of the basket. Assume that the player can be considered as a 95.0 kg point mass at a height of 2.0 m above the floor. If the basket rim has a spring constant of 7.4×10^3 N/m, by how much does the player displace the rim from the horizontal position?

37. A 35 kg child is jumping on a pogo stick. If the spring has a spring constant of 4945 N/m and it is compressed 25 cm, how high will the child bounce? (Assume that the mass of the pogo stick is negligible.)

38. A spring with a spring constant of 450 N/m hangs vertically. You attach a 2.2 kg block to it and allow the mass to fall. What is the maximum distance the block will fall before it begins moving upward?

39. A 48.0 kg in-line skater begins with a speed of 2.2 m/s. Friction also does –150 J of work on her. If her final speed is 5.9 m/s,
   (a) determine the change (final – initial) in her gravitational potential energy.
   (b) By how much, and in which direction (up or down), has her height changed?